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IRISH MEAN SEA LEVEL.

BY F. E. DIXON, B.A., F.R.MET.S.

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IRISH MEAN SEA LEVEL.

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Introduction.

It is well known that all the heights shown on Irish Ordnance Survey maps are measured from low water level in Dublin Bay—not the average low water, but that of a particular day, 8th April, 1837. This was found to be 20·90 feet below a fixed mark in the base of the Poolbeg lighthouse, and it is from that mark that most other heights have been obtained.* For many purposes the resultant heights are quite satisfactory, local differences of elevation being more important than the absolute values of individual heights. However, for some special work the absolute height is necessary, and in most countries it is now the practice to express the heights as above mean sea level This is best determined as the average of frequent observations at regular intervals but is usually regarded as almost equivalent to the mean tide level, the arithmetic mean between the average heights of the water at high tide and at low tide.

It has been stated (7) that it was as a result of Irish tidal observations in 1842 that the British Ordnance Survey decided to adopt mean sea level for their datum, it being discovered that the variation of the mean level, from place to place and from one tide to another, was far less than the variation of high or low water.

The Royal Irish Academy also realised the advantages of using the mean level, and in 1850 passed a resolution " that the levels in the new edition of the Ordnance Maps of Ireland be referred to the mean tide, in case the work be not already too far advanced to render such an alteration inexpedient " (10). Apparently it was inexpedient, and has continued so for almost one hundred years.

* Nautical charts show the heights above the local chart datums, which in some case differ appreciably from I.O.D.

Heights above mean sea level are especially important in Geophysics, including Meteorology. For example, all readings of pressure are " corrected " to Mean Sea Level before being entered on the maps for comparison with those of other stations. It was while investigating the barometer height-corrections that these notes were collected, but it is hoped that they will be of interest to others besides meteorologists, and may encourage the authorities to initiate more tidal surveys and otherwise increase our knowledge of the behaviour of the sea around our coasts.

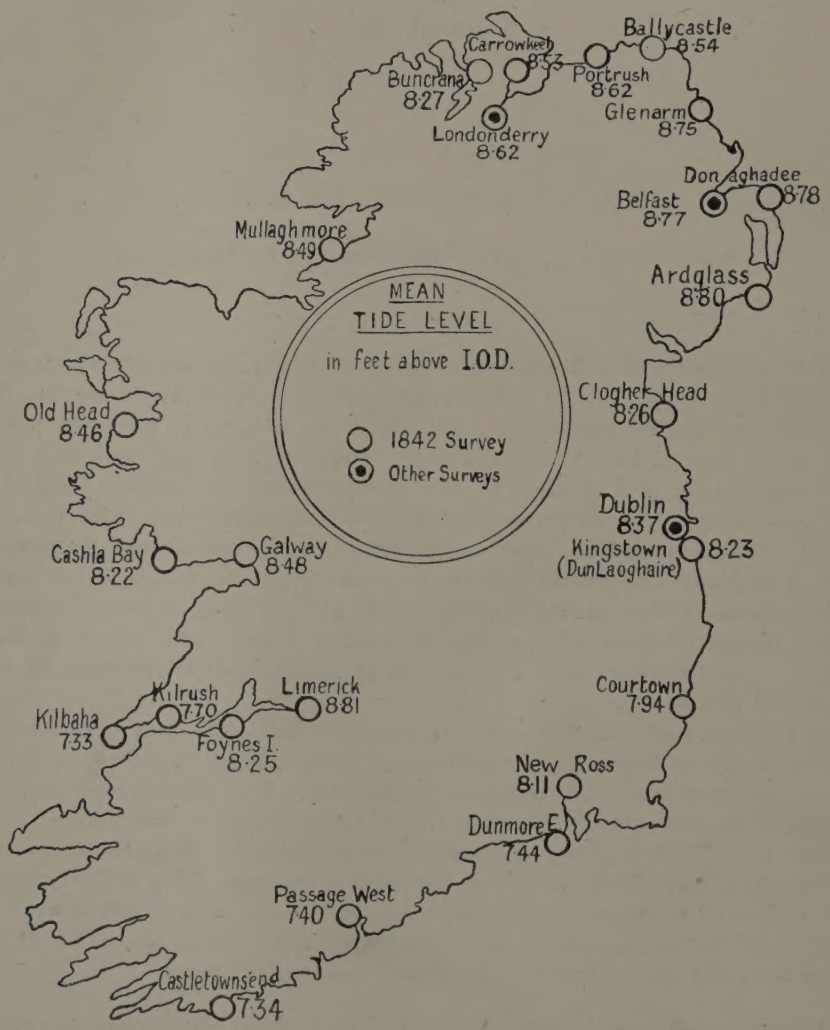

TABLE I.

Heights of Mean Tide Level above Irish Ordnance Datum.

Station	Authority and date of publication			Weight	Product
	Airy, 1845 feet	Cameron, 1855 feet	Pery, 1911 feet		
Kilbaha	6·57	6·578	7·335	4	29·340
Kilrush	7·36	7·358*	7·703	0	0
Foynes Island	8·10	8·092*	8·253	0	0
Limerick	8·57	8·567*	8·807	0	0
Cashla Bay	8·90	8·899	8·217	2	16·434
Galway	8·48	8·480	8·480	2	16·960
Old Head (Clew Bay)	8·72	8·725	8·457	3	25·371
Mullaghmore	9·05	9·047	8·492	5	42·460
Buncrana	8·32	8·369*	8·268	0	0
Portrush	8·64	8·682	8·617	2	17·234
Carrowkeel	8·99	9·029*	8·534	0	0
Ballycastle	8·44	8·479	8·538	1	8·538
Glenarm	8·66	8·709	8·754	1	8·754
Donaghadee	8·75	8·745	8·776	1	8·776
Ardglass	8·64	8·638	8·799	1	8·799
Clogher Head	8·18	8·184	8·259	2	16·518
Kingstown	8·39	8·395	8·234	2	16·468
Courtown	7·57	7·598	7·942	2	15·884
Dunmore East	6·75	6·753	7·438	3	22·314
New Ross	7·66	7·667*	8·111	0	0
Passage West	6·67	6·934	7·402	0	0
Castletownsend	6·37	6·660	7·343	4	29·372
Total	—	129·506	—	35	283·222
Adopted Mean	—	8·094	8·218	—	8·092

* Not used in computing the mean.

The Tide Survey, 1842

As part of the survey of Ireland, several lines were carefully levelled between 1839 and 1843, and there were observations of the tides at 22 stations round the coast. The tides were observed during two complete lunations from June to August, 1842, and the results were analysed by the great astronomer Airy (2), the heights all being reduced to a datum thirty feet below "a copper bolt fixed in the upper surface of the heelstone or hingestone of the gate of Buckingham Lock, Dublin." This was found to be 0·020 feet higher than the mark at the base of the Poolbeg lighthouse, and the tide datum was thus 9.08 feet below I.O.D.

Airy found that the mean height of the water was different for spring and neap tides, and was also dependent on whether the moon was ascending or descending. His final means are appended in Table I.

Yolland used Airy's figures in the publication dealing with the measurement of the Lough Foyle base (12), but Cameron re-analysed the data in his detailed report on the Irish levellings (5). Cameron's figures are included in Table I, and it is seen that they differed little from Airy's except that he evaluated them to 0·001 feet, which is certainly more precise than the data justify. Cameron carried the calculations a stage further by evaluating a mean level for the whole coast as the arithmetic mean of the figures, omitting stations in loughs or estuaries and so likely to be unrepresentative of conditions on the open coast. The resultant figure of 8·094 feet was in use for many years.

Some relevellings were made during the 1890's, and with their aid Pery adjusted Cameron's figures. The results were kindly supplied to me by the Ordnance Survey, and they also are quoted in Table I. From them the mean value for the country was deduced as 8·218 feet, and this was adopted from 25th July, 1911. It is not clear how the value of 8·218 feet was obtained, as the mean for all the 22 stations is 8·217 feet, and the omission of the inland stations would decrease this figure. A further difficulty in establishing a mean for the coast is that there are several stations near together in the region of highest mean sea level, whereas there are fewer in the area of lowest mean level. (See Map.)

To allow for this I have evaluated an average by weighting the value for each station according to the length of coastline between it and the neighbouring stations.

Places in estuaries or loughs have been given zero weight and the others have been weighted from 1 to 5, the 5 being used for Mullaghmore, which is the only station in the counties of Donegal, Fermanagh, Leitrim and Sligo. Details of the weights used are given at the end of Table I and it is seen that the resultant average is 8·092 feet, or 8·1 feet approximately.

Sources of Error in the Determination

There are several possible sources of error :—

(1) Errors of levelling,

(2) Errors of observation of tides,

(3) Errors due to position of stations,

(4) Errors due to short period of tide survey.

(1) I am not qualified to discuss the errors of levelling, but they are likely to be small, and the effect on the mean for the whole coast is reduced by the averaging for so many stations. It is noteworthy that, although the relevelling of the 1890's revealed errors of as much as 0·757 feet (Kilbaha), the average error for the whole network was only 0·103 feet, and so the residual error is likely to be still smaller.

(2) Since the results of interest here are the means of observations of high and low water, errors of observation (if any) are likely to cancel out.

(3) Tide gauges in river mouths are naturally affected by the water flowing out from the rivers and so give higher readings than those elsewhere on the coast. The stations most influenced in this way have been ignored. Some of the remainder, notably Galway, may be slightly affected, but probably not undesirably so. The outflow from the rivers must play an important part in determining the sea level, and if only stations away from rivers were considered, the resultant average would undoubtedly be too small.

(4) A major source of error is the fact that the tidal observations extended over only two months, which is not sufficient to determine the mean value accurately. As will be seen from the data for Dublin (North Wall) quoted in Table 2, the monthly mean value fluctuates through over one foot, and even the annual mean varies nearly an inch above and below the long period average.

TABLE 2.

HEIGHTS OF MEAN TIDE LEVEL ABOVE IRISH ORDNANCE DATUM AT DUBLIN (NORTH WALL).

Unit—0·01 foot

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
1938	851	806	847	797	793	814	814	814	826	851	893	860	829
1939	**911**	847	814	843	830	801	839	806	822	860	893	864	844
1940	856	860	843	830	839	814	830	801	826	880	864	797	837
1941	860	893	822	822	818	835	856	839	814	839	876	810	840
1942	787	**768**	824	816	851	814	830	849	858	876	826	901	833
1943	889	785	812	818	814	826	843	868	853	897	830	824	838
1944	836	787	793	826	813	842	849	845	834	837	867	829	830
1945	789	826	797	833	860	841	841	837	845	872	866	903	842
Mean	847	821	819	823	827	823	838	832	835	864	864	849	837
Range	124	125	54	46	67	41	42	67	44	60	67	106	15
Mean Deviation	33	35	15	10	18	13	10	19	13	17	18	33	4
Standard Deviation	41	40	18	13	21	14	12	22	15	20	24	37	5

The observations in 1842 were made from June to August, a time of the year when the variations are small, the standard deviation (root-mean-square error) for a two months period centred in July being only 0·13 feet. Assuming "normal" distribution of the fluctuations, departures as great as three times the standard deviation may be expected. The mean of the observations during two summer months may, therefore, differ from the true value, or long-period average, by as much as $\pm$ 0·4 feet. The average value during the summer months is slightly below that for the whole year, so that the 1842 survey results are more likely to be too low than too high.

The above discussion is based on only the one station, but the variations at the other stations are likely to be similar. However, it is difficult to estimate how far they will affect the average for a network of stations. The fluctuations of sea level are due mainly to meteorological factors, some of which cause deviations of the same sign at all the stations, whereas others may be only local. Prolonged hot dry weather will cause intense evaporation and also reduce the outflow from rivers. Heavy rain will cause a slight rise in the water level. High barometric pressure depresses the sea surface and low pressure raises it. All these factors are likely to act similarly over the whole country so that the mean sea level for the coast will be modified accordingly. Another influence is wind, which causes piling up of water to leeward and depresses it to windward. Thus unusual prevalence of a particular wind direction causes high values on one coast and low on the opposite one, so that the mean for the country is not much altered.

It therefore seems likely that the average for a number of stations will be slightly less variable than the figures for any individual station.

Such data as are available for the pressure and wind in 1842 (6) do not suggest any great abnormality, so that the tide survey figures are probably fairly representative and are unlikely to deviate from the long period average by as much as the 0·4 feet mentioned above. This conclusion is supported by the good agreement between the 1842 figure for Kingstown (8.23 feet) and the 1938-45 average for Dublin (8·37 feet). It is unfortunate that the recent Kingstown records are not analysed, so that the difference between the two places could be accurately ascertained, but the difference of 0·14 feet may be due to the influence of Liffey water on the Dublin gauge, and certainly does not suggest that the 1842 survey measurement was very inaccurate. If the 1914 Dublin Port levellings were accepted, the mean tide level for Dublin would be 8·14 feet. (See next page).

Summing up, it seems probable that the average height of mean sea level above I.O.D., deduced as 8·1 feet is ascertained with an accuracy within $\pm$ 0·2 feet.

Other Tide Observations.

In 1850-1 the Royal Irish Academy organised tidal observations at a number of places, and the data were used to calculate diurnal and semidiurnal tides, etc., and to study tidal streams and co-tidal lines. Many papers were published in the Academy Proceedings and Transactions and in the Journal of the Royal Dublin Society, but in none of these papers have I found any computation of heights of mean sea level or mean tide level. Nor have I located any original data in a form from which such figures could be deduced.

The recording tide-gauge which yielded the data for Table 2 has been operated at Dublin (North Wall) for a great many years. Sir Robert Ball analysed the data for 30 days (3) in 1887, obtaining mean *sea* level as 8·49 feet above I.O.D. The mean *tide* level deduced from the same observations is 8·37 feet, in good agreement with other measurements for the Dublin region.

The accepted datum of this gauge is 1·43 feet above I.O.D., the same value that Ball used, although a re-levelling in 1914 yielded the value 1·20 feet. This is a big discrepancy over so short a distance, and one possible explanation is that there has been local subsidence.

There have been other tide measurements at various places, and the Admiralty Tide Tables (1) include predictions based on observations at Kingstown (Dún Laoghaire) 1909-10, Belfast 1913, Galway 1845-6, Queenstown (Cobh) 1907, and Londonderry 1935-6. The Londonderry figures have been published by the International Union of Geodesy and Geophysics (11), but are not suitable for discussing Mean Sea Level round the coast, as the observation point is too far up Lough Foyle.

The mean tide levels deduced from the Admiralty tables are :

Belfast	....	8·77 feet above I.O.D.
Galway	....	8·86 ,, ,, ,,
Kingstown	....	8·15 ,, ,, ,,
Londonderry	....	8·62 ,, ,, ,,
Queenstown	....	8·02 ,, ,, ,,

The Belfast, Dún Laoghaire, and Londonderry figures agree well with the results of the 1942 survey for the same localities. The Galway value of 8·86 feet is rather high, and may be based on an erroneous section of the first levelling. 8·02 feet for Cobh is appreciably higher than the 7·40 feet for Passage West, and is possibly more accurate, as the Passage West value seems lower than one would expect by comparison with Castletownsend or Dunmore East.

Variation Round the Coast.

As can be seen from Table I or the Map there is a uniform variation of the height of mean tide level above I.O.D., the water being highest in the Northeast and lowest in the Southwest. The range, from 7·33 feet at Kilbaha to 8·80 feet at Ardglass, is less than that shown by the earlier levellings, but still rather large and appreciably larger than the corresponding range in Great Britain, which is 0·8 feet between Newlyn in the extreme Southwest and Dunbar in the Northeast (8). The explanation is probably the narrowness of the North Channel, where the water is piled up by frictional influences. The slope from south to north can be partially explained by the distribution of pressure which is normally lowest to the North-northwest, but the range is sufficient to explain less than 0·1 feet of the difference in sea level.

Difference of British and Irish Ordnance Datums.

Although the triangulation of Great Britain and of Ireland have been carefully related, it has not been possible to connect the levellings of the two areas, and the

heights have been measured from the respective datums without any knowledge of the difference between them (1).

In 1879 a committee of the British Association estimated that there was a difference of 7·47 feet between the two datums, but this was calculated by assuming that the mean level round Ireland was the same as that at Liverpool (4), an assumption which is not easily justified.

This value, rounded off to the nearest foot (i.e. 7 feet), has been used at Irish meteorological stations for many years, to make their published results comparable with those for English stations. It now appears that this 7-foot correction has been to a now obsolete British datum, and not to mean sea level as was originally intended.

Acknowledgments.

Finally, I would like to express my gratitude to the Ordnance Survey of Ireland and to the Dublin Port and Docks Board for their generous assistance and for permission to publish the data they have kindly supplied to me.

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